CS-C3130 Information security
Home examination 2020-04
Lecturer: Tuomas Aura

Use of reference materials, computers and the web is allowed in this examination.

Important: You must solve the examination questions by yourself without help from others. Communication about the examination between students is not allowed before the submission deadline. Sharing of the examination questions with other people is not allowed.

Answer all 8 problems. Each problem gives the same maximum number of points. The examination points will be scaled so that they constitute 75% of the course grade.

Submit your solutions as a single PDF file of maximum 8 pages and minimum 11 pt font size to MyCourses (spring 2020 course space). The submission deadline is Friday 10 April 2020 at 21:00. Late submissions will not be marked. Please submit early to avoid last-minute problems.

1. Access control

Give examples of the following information security concepts at a university:

(a) No-write-down policy
(b) Sanitizing data before downgrading
(c) Covert channel
(d) Separation-of-duty policy
(e) Pseudonym
(f) Data deanonymization
(g) Consent (as in GDPR)
(h) Defense in depth
(i) Isolation
(j) Minimizing attack surface

2. User authentication

An online service has 1000 000 users. It authenticates the users with passwords, which the service provider selects randomly for the user. The passwords can consist of any printable ASCII characters. The password length has not been decided yet.

The service stores the passwords in a database as hash values. The hash function is SHA-256, which is computed on the concatenation of the username and password:

hash = SHA-256 (username | password)

The attacker, which could be a nation-state actor, is expected to gain access to the password database and mount a brute-force password-cracking attack on the hashes. A top-end GPU can compute 3000 million ($3 \cdot 10^9$) SHA-256 hashes in a second. The price of a GPU day is approximately $1 including the hardware, electricity and other costs.

Plot the following as functions of the password length:

(a) entropy of a password
(b) cost of cracking at least one user's password from the database (use a log scale)

Answer also these questions:

(c) How long does it take for the attacker to crack a password of 10 characters?
(d) Are there any weaknesses in the hashing scheme, and how could it be made stronger?

3. Data encryption

You are travelling with a laptop that has BitLocker encryption enabled for the hard disk. The laptop has a built-in TPM security module. When you start up the laptop, it goes directly to the Windows login screen.

At the Elbonian airport, an officer takes your powered-down laptop to a back office to be examined while his colleague interrogates you for an hour about your travel plans. Finally, they return the laptop to you and let you go.

Question: In what different ways could Elbonian secret police have gained access to the data on your laptop?

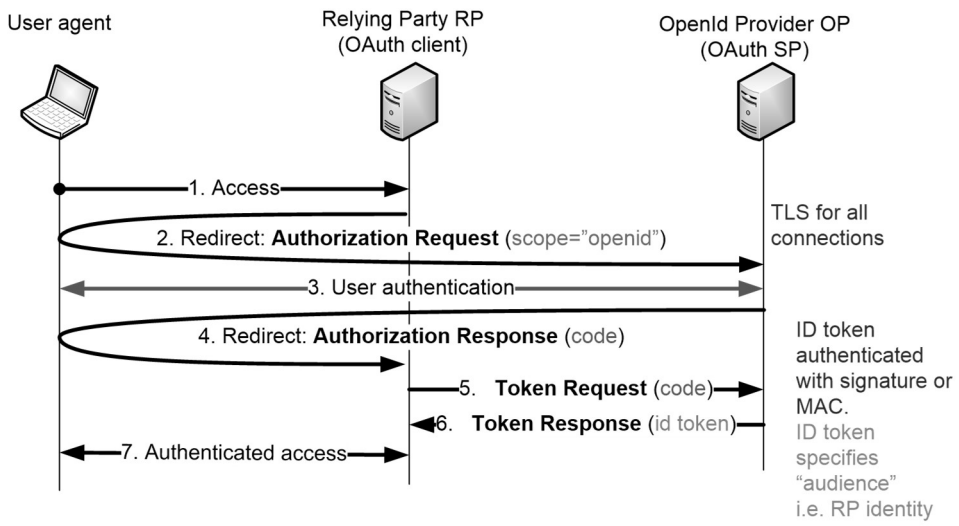
4. Threat analysis

Online meeting services such as Zoom, Microsoft Teams and Google Hangouts are now commonly used for business meetings, teamwork, online lectures, student tutoring, and personal conversations. Users can schedule meetings, invite attendees from inside and outside their organization, and even advertise open events with a link to the meeting. The service features include video and audio conferencing, screen sharing for presentations, remote assistance, team chat, file sharing, video recording, and transcription.

Analyze the security threats in online meeting tools when used at a university or school for educational purposes.

5. Identity management

The picture below shows the message flow in OpenId Connect:



Answer the following questions:

(a) How would the security be affected if TLS were not used for the connection between User and OP?
(b) How would the security be affected if TLS were not used for the connection between User to RP?
(c) How would the security be affected if the ID Token did not contain an RP identifier (the "audience" information)?

6. Payment systems and user authentication

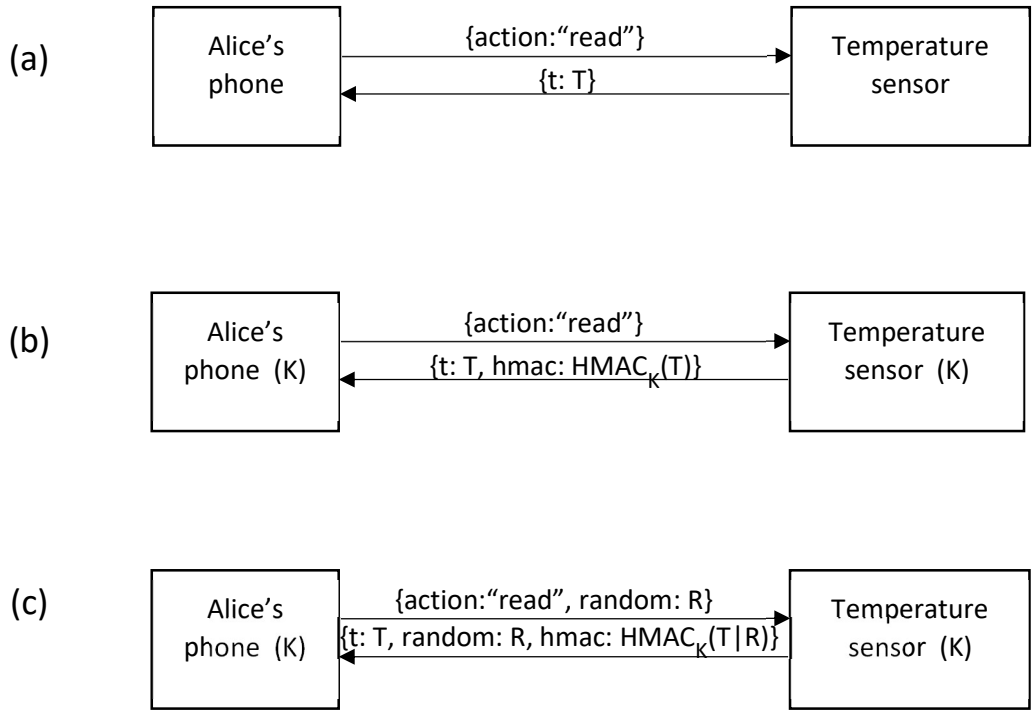
The secure printers at Aalto allow employees and students to register their contactless bus ticket as an authentication credential. Once registered, the user can authenticate to the secure printers by tapping their bus ticket on the printer's card reader. It is possible to use your bank card instead of the bus ticket. The authentication is based on reading the card's seven-byte unique identifier (UID), which is specified in the ISO 14443 standard.

Analyze the security of this authentication method. Compare also the security of using bank cards with using bus tickets.

7. Protocols

The diagrams below show three protocols for reading the temperature from a sensor over an open wireless network. In protocol (a), the user's phone sends a request to the sensor, which responds with the current temperature. In protocol (b), the phone and the sensor have been configured with a shared secret key K, and the response is protected with an HMAC computed with the key K. The phone verifies the HMAC before accepting the response as valid. In protocol (c), the request includes a 128-bit random number, which the sensor copies to the response. In addition to verifying the HMAC, the phone checks that the random number in the response has the correct value.

Your task: Compare the security of these three protocols.



8. Web security

In Appendix 1, there is a pretty-printed certificate chain. Explain in detail how the web browser checks this specific certificate chain and how the browser uses it to authenticate the website in TLS. (6p)

Notes: You do not need to explain the details of the TLS handshake protocol.

Appendix 1

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            03:3b:9e:d5:40:cd:f9:cb:2e:30:d7:42:5d:f1:48:9a:42:8b
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: C = US, O = Let's Encrypt, CN = Let's Encrypt Authority X3
        Validity
            Not Before: Feb 25 14:30:29 2020 GMT
            Not After : May 25 14:30:29 2020 GMT
        Subject: CN = *.vikaa.fi
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                RSA Public-Key: (2048 bit)
                Modulus:
                    00:bc:e9:a3:6b:c7:c7:b3:5b:59:28:e1:a0:02:6e:
                    81:f1:6b:d3:db:ff:7a:ba:a8:ef:a5:c1:26:7a:ea:
                    8f:27:af:d9:b0:e2:4a:55:7c:eb:1a:c5:18:1a:f2:
                    f2:b8:eb:09:ee:85:a2:21:61:d4:19:95:13:e9:6a:
                    2e:b7:b8:04:c8:b8:4e:90:4d:51:22:b2:25:7c:79:
                    92:4d:67:a5:ad:a1:68:ef:8c:89:a0:37:08:85:6f:
                    ed:ec:6f:a3:c7:42:1f:59:66:62:be:cc:fa:64:36:
                    51:68:fd:86:73:d3:d0:32:1b:6c:61:02:44:1d:ee:
                    7e:ea:5d:aa:8f:5e:3e:00:71:6b:55:42:62:67:aa:
                    f5:27:6d:70:26:fb:15:00:ad:ba:50:5c:b1:b8:30:
                    be:ab:92:71:5f:43:b8:3f:4c:88:a6:7b:69:16:a0:
                    6f:4f:e5:56:0a:c4:ab:cf:37:75:f7:ef:c8:30:65:
                    d9:78:b7:f8:3a:52:e4:7a:ee:6c:b2:f5:de:99:24:
                    d9:25:97:eb:c4:c9:84:3f:c7:8f:65:0c:60:5c:24:
                    f5:13:a4:27:89:31:49:0e:64:e1:9b:aa:bf:0b:21:
                    83:7c:34:cc:34:2a:18:6f:e2:0e:26:0c:61:e4:6d:
                    c3:4f:ea:43:85:52:2f:e7:28:4c:3f:e6:36:be:33:
                    3a:b5
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Key Usage: critical
                Digital Signature, Key Encipherment
            X509v3 Extended Key Usage:
                TLS Web Server Authentication, TLS Web Client Authentication
            X509v3 Basic Constraints: critical
                CA:FALSE
            X509v3 Subject Key Identifier:
                97:FD:B1:4C:88:52:0D:68:1C:24:F4:6C:BE:80:FE:AA:B2:40:B9:EE
            X509v3 Authority Key Identifier:
                keyid:A8:4A:6A:63:04:7D:DD:BA:E6:D1:39:B7:A6:45:65:EF:F3:A8:EC:A1

            Authority Information Access:
                OCSP - URI:http://ocsp.int-x3.letsencrypt.org
                CA Issuers - URI:http://cert.int-x3.letsencrypt.org/

            X509v3 Subject Alternative Name:
                DNS:*.vikaa.fi
            X509v3 Certificate Policies:
                Policy: 2.23.140.1.2.1
                Policy: 1.3.6.1.4.1.44947.1.1.1
                  CPS: http://cps.letsencrypt.org

            CT Precertificate SCTs:
                Signed Certificate Timestamp:
                    Version   : v1 (0x0)
                    Log ID    : E7:12:F2:B0:37:7E:1A:62:FB:8E:C9:0C:61:84:F1:EA:
                                7B:37:CB:56:1D:11:26:5B:F3:E0:F3:4B:F2:41:54:6E
                    Timestamp : Feb 25 15:30:29.248 2020 GMT
                    Extensions: none
                    Signature : ecdsa-with-SHA256
                                30:45:02:21:00:92:69:11:79:81:C3:45:71:23:2D:C0:
                                EE:B1:32:C9:E3:55:37:E9:BD:6F:8F:1D:A6:96:AC:F9:
                                A5:AB:3A:E0:D7:02:20:10:02:3B:B6:3F:89:BF:93:93:
                                09:26:0B:00:35:AC:E3:F0:E6:4F:39:75:C0:1B:C4:78:
                                46:E1:5E:67:72:04:85
                Signed Certificate Timestamp:
                    Version   : v1 (0x0)
                    Log ID    : B2:1E:05:CC:8B:A2:CD:8A:20:4E:87:66:F9:2B:B9:8A:
                                25:20:67:6B:DA:FA:70:E7:B2:49:53:2D:EF:8B:90:5E
                    Timestamp : Feb 25 15:30:29.239 2020 GMT
                    Extensions: none
                    Signature : ecdsa-with-SHA256
                                30:46:02:21:00:9F:EB:33:9A:68:E9:59:85:11:38:70:
                                A7:FC:2E:10:D6:9F:7C:9C:E8:A7:D8:3A:E6:4A:A6:2C:
                                DA:48:59:F9:71:02:21:00:B2:44:E4:72:3B:87:B3:43:
                                0F:34:21:6F:11:85:5F:FE:EF:6F:2A:DD:29:0D:06:D1:
                                7B:CF:E5:5F:B4:3D:F4:6B
    Signature Algorithm: sha256WithRSAEncryption
         92:55:cc:04:44:ad:8d:44:b7:1b:56:08:a4:80:23:ea:15:3d:
         71:51:c6:c6:37:64:cf:d8:31:ad:a6:8e:b2:52:5d:75:ad:f2:
         21:4b:86:e3:63:a2:84:5d:8e:0e:70:31:ed:a4:4e:ed:51:03:
         1b:9e:e0:60:aa:4a:7c:2e:04:72:94:14:fd:4b:ad:a4:c3:33:
         5d:da:77:ba:33:cf:b8:65:48:bd:44:0f:e5:cc:e0:2e:9b:5e:
         34:ef:15:a2:fc:ee:3f:10:fb:9d:7f:03:34:3f:6d:29:82:fe:
         f8:7f:41:4b:8b:51:44:f3:bf:51:bc:30:96:a9:53:33:05:72:
```

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         86:e2:26:34:a5:4f:e7:b8:78:d7:0d:78:99:3b:64:16:da:90:
         2c:67:9d:b1:de:9f:37:36:08:77:20:89:f9:54:fd:4b:e2:d9:
         e0:ad:df:65:42:54:b5:ad:23:ff:ac:31:e4:49:bb:fd:ff:db:
         11:cb:ae:13:37:e1:f7:97:5f:95:7c:67:48:80:3b:8e:a0:73:
         ae:54:ed:56:00:b9:d3:44:0f:21:81:f8:bd:0a:81:4e:08:4b:
         05:39:32:5c:76:12:ea:cc:05:3c:9b:ca:e7:44:fe:69:f1:7e:
         62:55:2e:94:13:fc:c1:d4:00:c1:5b:20:3e:ad:77:68:90:8c:
         c3:8c:68:46

Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            0a:01:41:42:00:00:01:53:85:73:6a:0b:85:ec:a7:08
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: O = Digital Signature Trust Co., CN = DST Root CA X3
        Validity
            Not Before: Mar 17 16:40:46 2016 GMT
            Not After : Mar 17 16:40:46 2021 GMT
        Subject: C = US, O = Let's Encrypt, CN = Let's Encrypt Authority X3
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                RSA Public-Key: (2048 bit)
                Modulus:
                    00:9c:d3:0c:f0:5a:e5:2e:47:b7:72:5d:37:83:b3:
                    68:63:30:ea:d7:35:26:19:25:e1:bd:be:35:f1:70:
                    92:2f:b7:b8:4b:41:05:ab:a9:9e:35:08:58:ec:b1:
                    2a:c4:68:87:0b:a3:e3:75:e4:e6:f3:a7:62:71:ba:
                    79:81:60:1f:d7:91:9a:9f:f3:d0:78:67:71:c8:69:
                    0e:95:91:cf:fe:e6:99:e9:60:3c:48:cc:7e:ca:4d:
                    77:12:24:9d:47:1b:5a:eb:b9:ec:1e:37:00:1c:9c:
                    ac:7b:a7:05:ea:ce:4a:eb:bd:41:e5:36:98:b9:cb:
                    fd:6d:3c:96:68:df:23:2a:42:90:0c:86:74:67:c8:
                    7f:a5:9a:b8:52:61:14:13:3f:65:e9:82:87:cb:db:
                    fa:0e:56:f6:86:89:f3:85:3f:97:86:af:b0:dc:1a:
                    ef:6b:0d:95:16:7d:c4:2b:a0:65:b2:99:04:36:75:
                    80:6b:ac:4a:f3:1b:90:49:78:2f:a2:96:4f:2a:20:
                    25:29:04:c6:74:c0:d0:31:cd:8f:31:38:95:16:ba:
                    a8:33:b8:43:f1:b1:1f:c3:30:7f:a2:79:31:13:3d:
                    2d:36:f8:e3:fc:f2:33:6a:b9:39:31:c5:af:c4:8d:
                    0d:1d:64:16:33:aa:fa:84:29:b6:d4:0b:c0:d8:7d:
                    c3:93
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Basic Constraints: critical
                CA:TRUE, pathlen:0
            X509v3 Key Usage: critical
                Digital Signature, Certificate Sign, CRL Sign
            Authority Information Access:
                OCSP - URI:http://isrg.trustid.ocsp.identrust.com
                CA Issuers - URI:http://apps.identrust.com/roots/dstrootcax3.p7c

            X509v3 Authority Key Identifier:
                keyid:C4:A7:B1:A4:7B:2C:71:FA:DB:E1:4B:90:75:FF:C4:15:60:85:89:10

            X509v3 Certificate Policies:
                Policy: 2.23.140.1.2.1
                Policy: 1.3.6.1.4.1.44947.1.1.1
                  CPS: http://cps.root-x1.letsencrypt.org

            X509v3 CRL Distribution Points:

                Full Name:
                  URI:http://crl.identrust.com/DSTROOTCAX3CRL.crl

            X509v3 Subject Key Identifier:
                A8:4A:6A:63:04:7D:DD:BA:E6:D1:39:B7:A6:45:65:EF:F3:A8:EC:A1
    Signature Algorithm: sha256WithRSAEncryption
         dd:33:d7:11:f3:63:58:38:dd:18:15:fb:09:55:be:76:56:b9:
         70:48:a5:69:47:27:7b:c2:24:08:92:f1:5a:1f:4a:12:29:37:
         24:74:51:1c:62:68:b8:cd:95:70:67:e5:f7:a4:bc:4e:28:51:
         cd:9b:e8:ae:87:9d:ea:d8:ba:5a:a1:01:9a:dc:f0:dd:6a:1d:
         6a:d8:3e:57:23:9e:a6:1e:04:62:9a:ff:d7:05:ca:b7:1f:3f:
         c0:0a:48:bc:94:b0:b6:65:62:e0:c1:54:e5:a3:2a:ad:20:c4:
         e9:e6:bb:dc:c8:f6:b5:c3:32:a3:98:cc:77:a8:e6:79:65:07:
         2b:cb:28:fe:3a:16:52:81:ce:52:0c:2e:5f:83:e8:d5:06:33:
         fb:77:6c:ce:40:ea:32:9e:1f:92:5c:41:c1:74:6c:5b:5d:0a:
         5f:33:cc:4d:9f:ac:38:f0:2f:7b:2c:62:9d:d9:a3:91:6f:25:
         1b:2f:90:b1:19:46:3d:f6:7e:1b:a6:7a:87:b9:a3:7a:6d:18:
         fa:25:a5:91:87:15:e0:f2:16:2f:58:b0:06:2f:2c:68:26:c6:
         4b:98:cd:da:9f:0c:f9:7f:90:ed:43:4a:12:44:4e:6f:73:7a:
         28:ea:a4:aa:6e:7b:4c:7d:87:dd:e0:c9:02:44:a7:87:af:c3:
         34:5b:b4:42

Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            44:af:b0:80:d6:a3:27:ba:89:30:39:86:2e:f8:40:6b
        Signature Algorithm: sha1WithRSAEncryption
        Issuer: O = Digital Signature Trust Co., CN = DST Root CA X3
        Validity
            Not Before: Sep 30 21:12:19 2000 GMT
            Not After : Sep 30 14:01:15 2021 GMT
        Subject: O = Digital Signature Trust Co., CN = DST Root CA X3
```

```
    Subject Public Key Info:
        Public Key Algorithm: rsaEncryption
            RSA Public-Key: (2048 bit)
            Modulus:
                00:df:af:e9:97:50:08:83:57:b4:cc:62:65:f6:90:
                82:ec:c7:d3:2c:6b:30:ca:5b:ec:d9:c3:7d:c7:40:
                c1:18:14:8b:e0:e8:33:76:49:2a:e3:3f:21:49:93:
                ac:4e:0e:af:3e:48:cb:65:ee:fc:d3:21:0f:65:d2:
                2a:d9:32:8f:8c:e5:f7:77:b0:12:7b:b5:95:c0:89:
                a3:a9:ba:ed:73:2e:7a:0c:06:32:83:a2:7e:8a:14:
                30:cd:11:a0:e1:2a:38:b9:79:0a:31:fd:50:bd:80:
                65:df:b7:51:63:83:c8:e2:88:61:ea:4b:61:81:ec:
                52:6b:b9:a2:e2:4b:1a:28:9f:48:a3:9e:0c:da:09:
                8e:3e:17:2e:1e:dd:20:df:5b:c6:2a:8a:ab:2e:bd:
                70:ad:c5:0b:1a:25:90:74:72:c5:7b:6a:ab:34:d6:
                30:89:ff:e5:68:13:7b:54:0b:c8:d6:ae:ec:5a:9c:
                92:1e:3d:64:b3:8c:c6:df:bf:c9:41:70:ec:16:72:
                d5:26:ec:38:55:39:43:d0:fc:fd:18:5c:40:f1:97:
                eb:d5:9a:9b:8d:1d:ba:da:25:b9:c6:d8:df:c1:15:
                02:3a:ab:da:6e:f1:3e:2e:f5:5c:08:9c:3c:d6:83:
                69:e4:10:9b:19:2a:b6:29:57:e3:e5:3d:9b:9f:f0:
                02:5d
            Exponent: 65537 (0x10001)
    X509v3 extensions:
        X509v3 Basic Constraints: critical
            CA:TRUE
        X509v3 Key Usage: critical
            Certificate Sign, CRL Sign
        X509v3 Subject Key Identifier:
            C4:A7:B1:A4:7B:2C:71:FA:DB:E1:4B:90:75:FF:C4:15:60:85:89:10
Signature Algorithm: sha1WithRSAEncryption
     a3:1a:2c:9b:17:00:5c:a9:1e:ee:28:66:37:3a:bf:83:c7:3f:
     4b:c3:09:a0:95:20:5d:e3:d9:59:44:d2:3e:0d:3e:bd:8a:4b:
     a0:74:1f:ce:10:82:9c:74:1a:1d:7e:98:1a:dd:cb:13:4b:b3:
     20:44:e4:91:e9:cc:fc:7d:a5:db:6a:e5:fe:e6:fd:e0:4e:dd:
     b7:00:3a:b5:70:49:af:f2:e5:eb:02:f1:d1:02:8b:19:cb:94:
     3a:5e:48:c4:18:1e:58:19:5f:1e:02:5a:f0:0c:f1:b1:ad:a9:
     dc:59:86:8b:6e:e9:91:f5:86:ca:fa:b9:66:33:aa:59:5b:ce:
     e2:a7:16:73:47:cb:2b:cc:99:b0:37:48:cf:e3:56:4b:f5:cf:
     0f:0c:72:32:87:c6:f0:44:bb:53:72:6d:43:f5:26:48:9a:52:
     67:b7:58:ab:fe:67:76:71:78:db:0d:a2:56:14:13:39:24:31:
     85:a2:a8:02:5a:30:47:e1:dd:50:07:bc:02:09:90:00:eb:64:
     63:60:9b:16:bc:88:c9:12:e6:d2:7d:91:8b:f9:3d:32:8d:65:
     b4:e9:7c:b1:57:76:ea:c5:b6:28:39:bf:15:65:1c:c8:f6:77:
     96:6a:0a:8d:77:0b:d8:91:0b:04:8e:07:db:29:b6:0a:ee:9d:
     82:35:35:10
```